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THE Maps are those of the Ordnance Survey, geologically coloured by the Geological Survey of Great Britain and Ireland under the Superintendence of Prof. A. C. RAMSAY, LL.D., F.R.S., &c., Director-General. The various Formations are traced and coloured in all their Subdivisions.

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MEMOIRS OF THE GEOLOGICAL SURVEY.

ENGLAND AND WALES.

THE

GEOLOGY OF PARTS OF NOTTINGHAMSHIRE, YORKSHIRE, AND DERBYSHIRE.

(EXPLANATION OF QUARTER SHEET No. 82 N.E.) Old Series

BY

W. TALBOT AVELINE, F.G.S.

SECOND EDITION.

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NOTICE.

THE first edition of this Memoir was published in 1861. Since then discoveries have been made, which have led to some modifications in the classification of the sub-divisions of the Coal-Measures and of the Permian strata. One of the results is, that the Red Rock of Rotherham, and its equivalents in this sheet formerly by most geologists considered to be of Permian age on account of their lying on an eroded surface, have been shown to belong to the Upper Coal-Measures. This position is proved by MR. AVELINE, not only in connexion with the behaviour of the strata that partly form the surface of the ground, but also by the mode of occurrence of the same Red Rocks in the well-known Shireoaks Coal-pit, where, in the shaft, beds of shale, ironstone, and coal, similar to those below "the Red Rock" were also found above it.

Other improvements, of a minor kind, are here and there inserted in this edition.

ANDREW C. RAMSAY,
Director General.

L 488. Wt. 19603.

NOTICE.

THE district comprised in Quarter-sheet 82 N.E. of the Geological Survey Map of England and Wales, and described in the following pages, constitutes a portion of the south-eastern edge of the Yorkshire and Derbyshire Coalfield, of which, though principally occupied by Permian and Triassic rocks, it forms a part, the Coal-Measures being concealed by these overlapping beds, but proved to extend beneath them.

The area was surveyed in 1857–58 by MR. AVELINE, and the first edition of this Explanation was published in 1861.

The nomenclature of the few fossils known from this district, has been revised by MR. ETHERIDGE.

Besides the important Coal-seams, as yet but partially worked, that underlie much, if not the whole of the district, the upper part of the Carboniferous and lower part of the Permian series afford valuable building- and grindstones, one of which, the North Anston stone, was selected by the Royal Commissioners for the Houses of Parliament.

H. W. BRISTOW,
Senior Director.

Geological Survey Office,
28, Jermyn Street, London, S.W.
22nd November 1879.

CONTENTS.

THE

GEOLOGY OF PARTS OF NOTTINGHAMSHIRE, YORKSHIRE, AND DERBYSHIRE.

THE district delineated on this map comprises an area of about 170 square miles in Yorkshire, Nottinghamshire, and Derbyshire. The principal towns are Bawtry and Tickhill in Yorkshire, and Retford and Worksop in Nottinghamshire. Only a very small portion of Derbyshire lies within the district; the areas of the other two counties are about equal.

The river Idle flows from south to north through the western part of the district. The smaller rivers and brooks that drain the country into the Idle have a general flow from west to east

The physical features of the district are very variable, and much cut up into hill and dale, but the chief features are a succession of ridges, with their steep sides facing the west, and their gentler slopes towards the east; and if these ridges were not so much cut up by cross valleys, and interrupted by minor undulations, they would be still more marked. One of these steep escarpments strikes from the northern edge of the district, 2 miles north-west of Maltby, southwards to the western border of the map, 1½ miles south of Harthill. Another from the northern border, 2 miles west of Tickhill, runs southward to near Worksop, and a third ridge from a mile east of Tickhill to the Manor Park, near Worksop. Besides these there are several minor ridges of the same kind. All these features, as well as the varieties of soil, are due to geological causes.

The geological formations that occur in this country, represented on the map by the different colours, letters, and figures, are given in the following Table.

ALLUVIUM.			
TRIAS or NEW RED SANDSTONE, f	Keuper	Red Marl and Sandstone	f^6
		Waterstones (Porous Sandstones and Marls)	f^5
	Bunter	Pebble Beds or Conglomerate	f^2
		Lower Soft Red Sandstone	f^1
PERMIAN or MAGNESIAN LIMESTONE SERIES, e		Upper Marls	e^5
		Upper Magnesian Limestone	e^4
		Middle Marls and Sandstones	e^3
		Lower Magnesian Limestone	e^2
		Quicksand	e^1
CARBONIFEROUS, d		Upper Coal-measures	d^5
		Lower Coal-measures	d^5

The relative positions of these formations is shown in the woodcut.

Besides the above formations, there is a superficial deposit of drift composed of gravel, sand, and clay, that is not shown by colour on the map. It is spread thinly and indifferently over the other formations.

The white lines mark the faults or dislocations. The small arrows point to the direction in which the beds are inclined; and the numbers by the side of those arrows, shew the amount, in degrees, of that inclination.

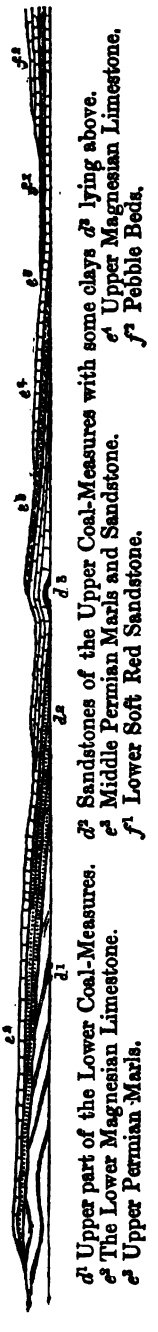
COAL-MEASURES.

The terms Upper and Lower Coal-Measures used in these explanations are only provisional terms for a Local Division, without reference to the well-known divisions in the Coal-Measures in this and other districts, the "Lower Coal-Measures" here meaning the great mass of coal-bearing strata, and the "Upper Coal-Measures," a set of red or purple sandstones with a few thin coals, lying unconformably on the Lower beds.

Lower Coal-measures.

The Lower Coal-measures of this district form a small portion of the eastern border of the South Yorkshire coal-field,* and it is only some of the highest beds of that field, which do not contain the thick workable coals, that come to the surface. There is only one small bed of coal that crops within this district. This has been worked at Brook-house, near Laughton-en-le-Morthen, but the pits are now abandoned. This coal crops in the Brook-house Valley, but I found it impossible to trace it for any distance. Although none of the thick coal-beds of the South Yorkshire coal-field come to the surface here, they, or many of them, must be present below, but at a considerable depth. It was from the knowledge

Section shewing the relative Position of the Formations from the Coal-Measures, near North Anston, to the Pebble Beds of the Bunter Sandstone, East of Carlton.



* A fuller description of the Coal-measures in the Yorkshire part of the district will be found in the Memoir on the Yorkshire Coal-field, published in 1878.

of this superposition of the strata, coupled with good geological measurements and calculations, that the Duke of Newcastle was led to undertake the important enterprise of sinking two pits on his property at Shireoaks, under the superintendence of Mr. JOHN LANCASTER. A paper giving a history of these pits, and the details of the beds passed through in the sinkings, was read before the Geological Society on the 1st June 1859, and was afterwards published in their Journal,* by Messrs. LANCASTER and WRIGHT, the latter gentleman being then manager of the colliery. From this paper we learn that the sinkings were commenced in March 1854, and after meeting with considerable difficulties, the first thick coal of 4 feet 6 inches, and of good quality, was cut at a depth of 346 yards. This coal is supposed to be the Wathwood Coal of the Derbyshire and South Yorkshire districts. On the 1st of February 1859, the "Top Hard Coal" was reached at a depth of 510 yards. This well-known coal, sometimes called the "Barnaley Coal," was the one sought after, and the fact that his calculations agreed within a few feet of the actual depth, reflects great credit on the geological knowledge and mining skill of Mr. LANCASTER.

The following section of the sinking of one of the Shireoaks Coal pits, and remarks thereon, is taken from the paper by Messrs. LANCASTER and WRIGHT; the bracketting of the beds into groups being by Mr. AVELINE.

"Table of the Strata passed through in sinking to the 'Top Hard Coal' by his Grace the Duke of Newcastle, at Shireoaks, Nottinghamshire."

	Description of Strata.	Thickness.			Depth.		
		Yds.	ft.	in.	Yds.	ft.	in.
PERMIAN.	Permian marls and sandstone	18	2	6	18	2	6
	Yellow limestone	18	2	8	37	2	2
	Grey limestone	15	1	0	53	0	2
	Blue shale and rock	6	2	3	59	2	5
	Blue shale	11	0	9	71	0	2
	Sand rock	0	1	8	71	1	10
UPPER COAL-MEASURES.	Warren Earth	1	0	0	72	1	10
	Blue and red bands with ironstone	1	2	11	74	1	9
	Ironstone	0	1	4	75	0	1
	Black shale	0	0	2	75	0	3
	Shale and rock	10	0	0	85	0	3
	The **Manor Coal**	0	2	0	85	2	3
	Blue shale	5	0	0	90	2	3
	Grey and red rock†	66	0	0	156	2	3
LOWER COAL-MEASURES.	**Coal**	0	1	4	157	0	7
	Rock and shale	13	0	8	170	1	3
	Black shale	0	2	6	171	0	9
	Fire-clay	2	0	2	173	0	11
	Coal *and black shale*	0	1	4	173	2	3
	Shale	3	2	10	177	2	1
	Coal	0	1	4	178	0	5
	Fire-clay	2	1	3	180	1	8
	Shaly **Coal** *and ironstone, 4 inches*	0	1	6	181	0	2
	Shale	5	2	3	186	2	5
	Coal	0	0	9	187	0	2
	Fire-clay	0	2	7	187	2	9
	Shale and coal	0	1	0	188	0	9
	Rock	2	2	4	191	0	1
	Coal	0	0	8	191	0	9
	Blue shale	6	0	0	197	0	9

* *Quart. Journ. Geol. Soc.*, vol. xvi., p. 137.

† Believed to represent the Rotherham Red Rock.

Table of Strata—*continued.*

	Description of Strata.	Thickness.			Depth.		
		Yds.	ft.	in.	Yds.	ft.	in.
LOWER COAL-MEASURES.	Shaly **Coal**	0	0	3	197	1	0
	Rock and metal	8	2	4	206	0	4
	Coal *and black shale*	0	1	11	206	2	3
	Shale	1	2	9	208	2	0
	Rock bands	10	2	3	219	1	3
	Black shale and ironstone, 5 inches	4	0	4	223	1	7
	Fire-clay and shale	2	2	0	226	0	7
	Coal	0	1	2	226	1	9
	Shale and rock	5	1	0	231	2	9
	Coal	0	0	4	232	0	1
	Shale and rock	3	0	4	235	0	5
	Coal *and shale*	0	0	6	235	0	11
	Shale	3	0	5	238	1	4
	Bands of rock	10	2	4	249	0	8
	Shale and ironstone bands	10	2	6	260	0	2
	Shale	8	1	2	268	1	4
	Coal	0	0	8	268	2	0
	Rock and shale	8	0	7	276	2	7
	Coal	0	1	0	277	0	7
	Rock and shale	23	1	10	300	2	5
	Coal	0	0	7	301	0	0
	Shale and ironstone	16	2	0	317	2	0
	Inferior **coal**	0	1	2	318	0	2
	Shale	7	1	6	323	1	8
	Coal	0	0	5	324	2	1
	Rock and shale	15	0	0	339	2	1
	SHIREOAKS, MELTON, CLOWN, OR WATERWOOD COAL	1	1	4	340	0	5
	Shale	18	1	0	358	1	6
	Inferior **Coal**	1	0	2	359	1	8
	Warren Earth	1	1	6	361	0	2
	Strong rock	4	0	5	365	0	7
	Measures (with thin beds of **coal**)	15	0	5	380	1	0
	FURNACE-COAL	0	2	8	381	0	8
	Measures	8	0	1	389	0	9
	Coal	0	1	6	389	2	3
	Fire-clay	0	1	4	390	0	7
	Coal	0	1	0	390	1	7
	Shale and rock	13	2	8	404	0	3
	Coal	0	2	1	404	2	4
	Shale and rock	3	2	9	408	2	1
	Coal	0	0	6	408	2	7
	Shale and rock	18	2	3	427	1	10
	HALLES COAL	1	0	1	428	1	11
	Dirt in **coal**	0	0	7	528	2	6
	Rock and shale	10	2	2	439	1	8
	Shell-bed	0	0	2	439	1	10
	Shale	19	2	3	459	1	1
	Coal	0	1	4	459	2	5
	Shale and rock	42	2	1	502	1	6
	Coal	0	0	7	502	2	1
	Shale	5	0	7	507	2	8
	HARD COAL	1	0	9	509	0	5
	Dark Warren Earth	0	0	3	509	0	8
	Blue shale	2	1	6	511	2	2
	Proved by Boring.						
	Rock and shale	14	1	4	526	0	6
	Coal *and shale*	0	0	7	526	1	1
	Blue shale and Ironstone-bands	11	0	0	537	1	1
	Ironstone	0	0	7	537	1	8
	Rock and shale	8	1	5	546	0	1
	Black shale	0	2	5	546	2	6
	Warren Earth	0	1	2	547	0	8

"The following are the points of greatest interest proved by this sinking:—

1. The existence of a soft sand-rock at the bottom of the Permian beds in this district, which seems to be the equivalent of the "Quick-sand" of the north.

2. The absence of any workable seam of coal in this district, at least in the 300 yards of Coal-Measures above the "Wathwood" or "Shireoaks Thick Coal." Thirty-seven feet of coal were passed through in the sinking, but only four seams are of a workable thickness.

3. The existence of a Red Ironstone in the upper measures, which promises to be of great commercial value.

4. The "Top Hard Coal" seems to thin out towards the east under the Magnesian Limestone; for at Killamarsh and near its outcrop, six miles west of Shireoak, it is 6 feet thick, while with us it is only 3 feet 9 inches.

The "Wathwood coal" being found within one yard of the depth, calculated from the dip of the strata, would lead to the supposition that the new district is remarkably free from faults; and this supposition is further borne out by the large bodies of water met with—so large, indeed, that the greatest credit is due to the Duke of Newcastle for the perseverance he has shown in carrying on the undertaking single-handed.

We find the dip decreases considerably towards the east, the strata coming more into a basin-form. At the Comberwood Colliery the dip varies from 1 in 6 to 1 in 12, while at Shireoaks it undulates considerably; but we have never observed it more than 1 in 36."

It will be seen, on referring to the section of the Shireoaks pit, that the Coal-Measures are made up of numerous beds of sandstone (rock), shale, clay, ironstone, and coal. Few of the softer beds of the measures are exposed at the surface in this district. The nearest good section is that exposed in the cutting of the Manchester, Sheffield, and Lincoln Railway, just outside the western border of the quarter-sheet, where may be seen sandstone, clays, and thin beds of coal, like those mentioned in the pit section. There is one brickyard in the Coal-Measure clays about a mile to the north-west of North Anston.

In the north-west corner of this district are some yellow, and light and dark-brown sandstones, much softer than the red rocks of the Upper Coal-Measures. These sandstones are extensively quarried for the softer grindstones used in the Sheffield cutlery-works. Their exact position in the upper part of the Lower Coal-Measures is uncertain. That they are high up in the measures there can be no doubt, but I have never seen a clear section in this district, showing what beds lie above them. If the Shireoaks pit-section be referred to, it will be seen that these beds were not passed through, or at least no great thickness of soft sandstones were found below the 66 yards of red and grey rock, although where they are quarried they must be of considerable thickness. From what I have seen of them here and in other places, I believe that they occur in large lenticular masses which do not extend to the southern part of the district. No coal-beds, shale, or clay, are found interstratified with them, and they make a dry sandy country like that over the red rocks, only that the soil is of a brown colour instead of being red. Finding sometimes a red tinge in these beds, and that now and then they assumed a harder character, I was led at first to speculate whether or not these and the red beds might not be only modifications of each other; but the evidence, gathered in other

districts, shows that the soft grindstone-beds are in the Lower Coal-measures.

Besides being used for grindstones the soft sandstones are worked into cisterns, troughs, pillars, &c. The best exposures of these beds are in the quarries near Wickersley, west of this district, in which are found the common fossil plants of the Coal-measures.

Upper Coal-measures.

In the higher part of the Shireoaks pit-section may be noticed some grey and red rock, 66 yards in thickness, believed to represent the "Rotherham Red Rock," a rock which is well known as affording the hard grindstones used in the Sheffield cutlery-works. This rock may be seen near Harthill and South Anston in this district (82 N.E.), where it appears to lie unconformably on the beds below. There is certainly no indication of a passage from the underlying shales, clays, and soft sandstones into these red beds, the junction, wherever it is seen between Harthill and South Anston, being always well defined. But it will be seen by the section of the Shireoaks pit, that other beds of coal, shale, and ironstone like those below lie above the grey and red rock. It was not until the pit was sunk at Shireoaks that it was known for certain that these coal-bearing strata were above the red rock in this district; although there is some indication of them at Harthill, where, however, the section is far from being clear and satisfactory. But besides the evidence of coal being found above the red rock, the fossil plants in it are also common to the Coal-Measures. This led myself and others to consider these red rocks as forming an upper division of the Coal-Measures, resting unconformably on the lower strata of the same great formation, and were not Permian, that is, the Lower Red Sandstone of Sedgwick or the Rothliegende of Murchison.*

The red rock is well exposed in a quarry at Harthill, where it is worked for scythe-stones. Here, in a face of 40 feet, may be seen thick irregular beds of purple-grey grit, much cut up with joints and lines of false bedding. West of Harthill Grange there is another quarry of these grits, but of a lighter colour. The grits in this quarry are overlaid by sandy shale and purplish marl. A little way south of this quarry the red rock disappears, being overlapped by the Magnesian Limestone. The same rock may also be seen in quarries near South Anston, Todwick Grange, and Todwick Old Hall. In most of the quarries fragments of fossil plants occur, and the following list by Mr. J. W. Salter is from specimens collected at Harthill:—

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* This view is now adopted by the Geological Survey. In the earlier additions of the map these Harthill and Rotherham Red Sandstones, by the direction of the late Sir Roderick Murchison, Director General of the Geological Survey, adopting the views of Professor Sedgwick, were coloured as Lower Red Sandstone or Rothliegende. May 1879.

Sagenaria (*Lepidodendron*) *aculeata.* Presl.
Lepidodendron obovatum? Sternb.
Sigillaria, large indeterminable fragments.
Calamites Suckovii. Brongn.

The ground occupied by the Harthill sandstones in this district and "Red Rock of Rotherham" in the adjoining one, on the west forms a strong contrast to that of the coal-formation generally; for while the latter makes a heavy clay soil, very wet and of a dark-brown colour, the former is covered by a light sandy soil, very dry, and coloured red. Springs of water are everywhere thrown out around the base of the red rock, which helps to mark its lower line of boundary. A careful survey of the district convinces me that the Rotherham rock is the equivalent of that of Harthill and South Anston, being a large outlier resting unconformably on the Lower Coal-Measures.

In a quarry south of Harthill Clump, the lowest bed seen is a fine-grained red sandstone. Lying on this is a brown compressed sand, and then a few gritty bands. Close above there is a quarry of Magnesian Limestone.

On the north side of Harthill Clump, red and light coloured clays lie between the limestone and purple and brown grits, which grits are the equivalents of the Harthill rock.

The next section, immediately below the limestone, is on the road leading from Harthill to Harthill Grange. Here, close under the limestone, are brown sandstones and sandy shales, and below these again are the purple-grey scythestone grits of Harthill.

In Hawkwood, east of Harthill, a yellow quicksand is seen below the limestone; but here, instead of its lying between the limestone and the red rock, to judge from the appearance of the ground (for there is no visible section), some thickness of clay or other soft rock intervenes; and this seems to agree with the Shireoaks pit-section, where 19 yards of strata with both coal and ironstone lie between the quicksand and the grey and red sandstone. But this state of things is not continued for any distance, for the limestone quickly overlaps this small area, and rests direct on the red sandstones or scythestone grits.

Between this and South Anston nothing is known between the limestone and the red sandstones, but there are not many sections showing the junction. In the quarries west of Kiverton station it is known that grits are immediately under the limestone.

In the valley between North and South Anston, sections of the strata may be seen at intervals in the bed or by the side of the brook from the road between the two villages, for some way down. These sections are of Lower Coal-Measure shales, clays, and sandstones, and in one place (near the foot-bridge) there is a small bed of coal. These have all a westerly dip up the brook, just the reverse of the inclination of the Magnesian Limestone, which dips down the brook. The Lower Coal-Measures dip at angles of 20°, while that of the limestone is only 2° or 3°. Below the stepping-stones in the wood there are exposed in the bed of the brook thin-bedded yellow sandstones dipping S.W. at an angle of 22°, and

these may be seen for some way down; but on the bank above them are purple and grey thin-bedded sandstones dipping down the brook at a small angle till at length they occupy its bed in place of the Lower Coal-Measures. Apparently there is here complete uncomformity between these beds and the Lower Coal-Measures, and the former also appear to lie under and conformable to the limestone. When I surveyed this part I considered that these beds were the same as the Harthill and Rotherham red rock, and this at once set to rest the question of unconformity between that rock and the Lower Coal-Measures below them.

At North Anston the Magnesian Limestone lies directly on red grits, which I could not distinguish from those on the opposite side of the valley to the west of South Anston. These beds cannot be traced much farther than a little way north of the village, which may be partly owing to the débris of the limestone over these beds; but no doubt they thin away or get overlapped somewhere between North Anston and Dinnington Chapel, or they would have been detected.

The next spot where any beds show themselves immediately below the limestone is near Laughton-en-le-Morthen, where, on the west side of Toe Lane, in an old limestone-quarry, there is some purple marly shale, and on the west side of the village similar shales are interstratified with the bottom beds of the limestone, and this is the first certain indication of any purple or red beds being so closely connected with the limestone.* Near this the yellow quicksand again occurs below the limestone, in a small pit on the north-west side of the village as well as on the south side of the valley a mile north-east of the village, and here no red rock is seen.

North of Brookhouse a broken section may be seen by the roadside. The first beds that are exposed below the limestone are purple and red marly shales, the next are thin beds of red sandstone, and then thick beds of soft yellow sandstone. The last had much the appearance of the common sandstone of the Lower Coal-measures, but the section does not show any junction. Along the north side of the Brookhouse Valley there appears to be a continuous thin bed of red sandstone below the limestone, for fragments are found on the fields, and sometimes it is marked by a belt of red soil. Red beds may be seen at Thurcroft Hall, and from thence northward a red bank marks the base of the limestone, with occasional fragments of red shale or marl.†

At Hooton Levitt, red and blue clays containing nodules of red iron ore are found immediately below the limestone.

Between Maltby and Roche Abbey the limestone forms the steep sides of the valley with red beds at the bottom while the brook that flows through the valley has cut down to the Lower Coal-measures. This shows that the red beds here form a thin

* These are no doubt marly beds of Permian age and not Carboniferous.

† These Red Sandstones, shales, and marls may be mere stained Coal-Measures. either Upper or Lower.

regular band at the base of the limestone. A section showing all three formations in close proximity may be be seen at Hooton Levitt Mill, where the brook has cut a deep gully.

In following the base of the limestone northward from Maltby it will be found that for some distance the débris from old quarries conceals any beds that lie immediately below, but at Lilly Hall Farm red marls containing nodules of red ironstone have been dug out under the limestone. A little north of this there is a small quarry of red sandstone, and by the road side at Fardells House a little purple shale is seen.

Red ground appears a little to the north of Fardells House, but there is some uncertainty just here, the ground being very obscure. The top of the ground is marly, but a short way to the north in the next district, there are quarries of hard red grindstone-grit close below the limestone. An outlying patch of red sandstone occurs to the west of Laughton-en-le-Morthen.

PERMIAN.

The Permian beds of this district consist of two great bands of limestone, separated from each other by marls and sandstone. Marls also occasionally overlie the Upper Limestone, and in a few localities a thin band of quicksand is found below the Lower Limestone. These formations are well known as the Magnesian Limestone series of the Permian. The Lower Limestone containing sometimes as much as 40 per cent. of carbonate of magnesia, but in the Upper Limestone the percentage of carbonate of magnesia is very small.

Quick Sand.

In the Shireoaks pit-section it will be seen that the sixth division from the top is a sand-rock 1 foot 8 inches in thickness. This is considered by the authors of the paper on that pit to be the bottom of the Permian strata, because (being unconsolidated) it resembles certain sands noticed by Professor Sedgwick, and called by him "quicksand," which occur at the base of the Magnesian Limestone in the north. This quicksand, or one like it, is found in this district in several places. In some large open pits on the south side of Pebbly Dam, south of Harthill, there is about 20 feet of unconsolidated yellow sand, and this must be near its total thickness; for although its junction with the limestone is not seen, it lies close above the top of the pits, and the wet ground at the base of the pits points out the position of the clays of the Coal-measures. The difference in the thickness of the sand here and that in the Shireoaks pits, if they be the same, shows how irregular this bed is, but more than that, the sand is not to be found within a short distance on either side of the Pebble Dam sand pits. Going eastward it either dies out suddenly, or becomes so thin that it is impossible to trace it. It is only seen again in two other places in this district, at Hawkwood and Laughton-en-le-Morthen.

Lower Magnesian Limestone.

This is the most important division of the Permian formation of this district. It is extensively quarried for a building stone, and for being converted into lime. As the stone differs in character in different localities, I shall describe the rock in some of the principal quarries.

In *Streetly Quarries* near Worksop, the rock consists of a highly crystalline limestone. Some beds are very white, and the others vary in colour from white to grey and yellow. This stone is quarried in tolerably regular blocks from 2 to 3 feet thick: it takes a smooth polish, and is largely used as a building-stone. St. George's Church, Doncaster, was built with this stone.

At *Shireoaks Quarries* there occurs a hard and compact limestone of a light cream colour. The surfaces of the beds are rough and display a sort of fretted structure, which in a hand-specimen might at first sight be mistaken for weathering. This has been described by Professor Sedgwick, who remarks:—"In passing "into a solid state, some of these beds have penetrated each other; "so that their separation is not represented by a plane superficies, "but by a number of imperfectly crystalline points and protu- "berances, which give to the surfaces of the blocks an appearance "resembling artificial rustic work. These natural surfaces have "been occasionally used in ornamental architecture."*

Between the planes of the beds where this occurs there often lies a thin irregular layer of soft bluish marl, giving the impression that it is the residuum of a partial decomposition of the limestone; but whether the peculiar fretted structure in the limestone is necessarily connected with this circumstance I am unable to state. In a continuation of these quarries along the south side of the canal, the top beds produce large blocks (4 feet 9 inches × 4 feet 6 inches × 2 feet). These upper beds are softer than the lower; which are very hard, more compactly grained and thinner bedded, and more jointed than the top beds. The top beds are most used for building, the lower beds make the best lime.

At *Brancliff Lime-works* the rock is composed of very thick beds, especially the lower, which are hard and silicious and of a brownish-grey colour. The upper beds are light yellow, not quite so hard as the lower, but still very compact. These dip to the E.S.E. at an angle of about 5°. Some of the lower beds are pretty regular, so that rectangular blocks are obtained measuring 6 feet × 3 feet × 2½ feet, and paving-slabs measuring 4 feet × 3 feet × ½ foot.

At *Kiveton Park Station Quarries* the limestone is largely worked. It is a yellowish-white compact limestone, some of the beds being very hard. The lower beds of the quarries are 2 to 3 feet thick.

North Anston Quarries.—From these quarries much of the stone used in the Houses of Parliament was brought, the lower part only of the Palace at Westminster being built of the

* Rev. A. Sedgwick, *Trans. Geol. Soc.*, ser. 2, vol. iii., p. 84.

Bolsover and Mansfield Woodhouse Stone, which was that chosen by the Royal Commissioners. The North Anston Rock has rather a close grain and is very hard, and both bedding and joints are very regular, so as to produce large rectangular blocks measuring 8 feet × 3 feet × 1½ feet. The stone has not the beautiful colour or grain of the Bolsover Moor or the Mansfield Woodhouse Stone, but it appears equally hard, and has a regularity in bedding which the others do not possess. The beds of this quarry lie horizontally, which much facilitates quarrying.

Roche Abbey Quarry.—This is a beautifully white fine crystalline rock, but rather soft, especially in the lower beds. It has been extensively quarried for building-stone and sculpture work, but owing to the quarry being so far from any railroad or canal it is not now so much used. Blocks may be obtained averaging from 6 to 12 feet long, 1½ feet broad, and 1½ feet thick, and beds are sometimes found 2 feet thick, but owing to the irregularity of the bedding the occurrence of large blocks is very uncertain. A fresh fracture of this stone shows a surface as white as chalk with a sparkling lustre, more resembling loaf sugar than anything else; but, on exposure, the surface soon loses its white and sparkling appearance and becomes of a dull grey colour. The softness of this stone is against its being much used for buildings exposed to atmospheric influences; but in sheltered spots a lichen quickly forms on it, which is said to preserve it for ages. Some beds that lie below these quarries, and are the lowest in the series, may be seen in the valley, being in some parts very hard and compact, and producing the impression that they have been formed by the chemical decomposition and recomposition of the ingredients of the rock. The beds themselves are very irregular and broken.

These are the principal quarries of the district, but there are many smaller ones scattered over the country, and many road-cuttings and natural sections where these beds are well exposed. Among the latter are the crags near South Anston and in the Roche Abbey Valley.

The following section of the Lower Magnesian Limestone was obtained in sinking No. 2 coal-pit at Shireoaks:—

	ft.	in.
Permian marls and sandstone - - -		
Yellow limestone - - - - -	40	0
Light-blue "close stone" (probably compact limestone) - - - - - -	5	0
Dark-blue limestone - - - -	43	8
Limestone bands (6 to 12 inches), with bands of "blue metal" (? hard shale) - - -	19	0
Blue bind (shale) - - - - -	33	0
Grey sand-rock (quicksand) - - -	7	0*

Fossils are exceeding scarce in the Lower Limestone of this

* This was only 1 foot 8 inches thick in No. 1 Pit.

district, and it is only in some of its lower beds that I have observed any. The following is a list, drawn up by MR. SALTER, of the fossils collected by MR. GIBBS, in Dodiddle's Quarry, north of Laughton-en-le-Morthen :—

Terebratula (*elongata*) Schloth.	*Bakevellia* (*Gervillia*).
Productus horridus, Sow.	*Pleurotomaria antrina*, Schloth.
Avicula speluncaria, Schloth.	*Turbo*.

" These shells, though few, agree with those of the 'Lower or Shell Limestone' of PROF. KING, MR. HOWSE, and other writers."

By the side of Toe Lane, south of Laughton-en-le-Morthen, and in other places along the lower outcrop, I noticed a few casts of shells.

MIDDLE MARLS AND SANDSTONES.

These beds, consisting of red marls and soft sandstones of various colours, sometimes containing small pebbles, divide the Lower from the Upper Magnesian Limestone. They lie somewhat unconformably on the former, and there is no good section in this district showing a passage upwards into the latter. Throughout their course from south to north they vary considerably in thickness, but whether this is occasioned by overlaps of the Upper Limestone or by the thinning away and thickening of the beds themselves, there is no good evidence to show. I am more inclined to attribute these irregularities chiefly to variations in the thickness of the strata, although there may be occasionally small overlaps as well.

Commencing from the south, the first sections are to be seen to the west of Worksop Manor Park. At Ratcliff there are beds of red sandstone, which might easily be mistaken for the New Red mottled sandstone of the neighbouring districts, if it were not that the strata at Ratcliff are overlaid by red marl; whereas the red and mottled sandstone of the Bunter beds is always overlaid by the Pebble beds. The sandstone is thin-bedded, very unconsolidated, of a brownish-red colour, with light-yellow blotches. The bottom bed is a very soft red sand. The beds dip to the east at an angle of from 3° to 4°. The marl seen above the sandstone is of a deep-red colour. There are also found scattered over the ground, in a field on a higher level, fragments of thin flaggy sandstone precisely like those underlying the thin-bedded limestone west of Cuckney.* Red marls may be seen north of Ratcliff Grange, in Hob Wood, and in West Wood; and there are signs of old clay-pits on the north side of the road between Darfoulds and Manor Cottage.

On Red Hill there is an outlier, which, as far as can been seen, consists of red sand; and a very small outlier of sand lies a little farther north, and another at the Sand Pit near Southgate House.

In the brick-yard pits, between the canal and railroad, north-west of Worksop, there are blood-red marls, with reddish-brown

* See Memoir on Quarter-Sheet 82 S.W.

and white sandstones sometimes half a foot in thickness and rather hard in parts. Some of the white sandstone is very like the Upper Keuper Sandstone. The sandstone beds are thicker in the upper than in the lower part of the section, and there are about twelve feet of strata exposed in these pits, a whitish sandstone at the bottom not having been gone through.

A good section was exposed of these beds in the railway-cutting at Shireoaks, and in the coal-pits close by they were passed through, as shown in the following section :—

	ft.	in.
Sand - - -	4	0
Rocky red sandstone -	4	0
Light and red rock -	3	0
Red marl - - -	3	0
Red rock - - -	6	0
Red marl - - -	8	0
Light sandstone - -	1	6
Red marl - - -	3	6
Carried on - -	33	0

	ft.	in.
Brought forward -	33	0
Red sandstone - -	3	5
Red marl - - -	3	10
Light sandstone - -	2	9
Red marl - - -	1	2
Light sandstone - -	1	6
Total thickness -	45	8

This does not give the total thickness of the formation, for the pit was not begun in the uppermost beds. I do not, however, suppose it to be of much greater thickness.

To the west of Shireoaks by the sides of the railway and canal these beds are exposed in brickyards, showing deep-red and variegated marls and beds of red and brown soft sandstone with sandstone of a greenish colour, like the beds of Upper Keuper Sandstone in the New Red Marl. The beds lie quite horizontally.

In proceeding in a northerly direction the marls and sandstones are only to be seen occasionally in drains or other small openings. South of Walling Wells a small road-cutting exposes a few feet of these beds lying below the Upper Limestone. The broad spread of these beds and their seeming great thickness round Walling Wells Park is caused by undulations, the Lower Limestone, as before stated, being upheaved into a dome-shaped mass to the highest level in the park, where it is exposed in consequence of the denudation of the overlying marl and sandstone.

A section showing alternating beds of red marl and thin-bedded white sandstone, fine-grained and hard, like Upper Keuper Sandstone, may be seen in the brickyard north-west of Carlton. The waters of the lakes at South Carlton and at Langold are held up by the marls.

On reaching Letwell it will be found that the beds are only 20 feet thick, or less than half their thickness at Shireoaks. Some of the beds are exposed by the roadside west of Letwell Church. The lowest bed seen is about 4 feet of a coarse red sand with pebbles; the pebbles being thick at the base and few at the top of the bed. This pebble bed is overlaid by soft reddish-brown sandstone with seams of red marl; over this thin seams of light-coloured marly shale, then 6 inches of light-yellow soft sandstone, overlaid by thin seams of light-coloured marly shale. Above this come 6 inches of yellow sandstone with pebbles of white and coloured quartz. For about 10 feet above this the beds are not

exposed, but they probably consist of marls and sandstones, higher up, underlying the Upper Limestone, there are red marls with thin beds of a red-coloured flaggy sandstone. The limestone lying immediately on the marls is in thin beds, compact and yellow, with black spots. The marls with thin flaggy sandstones are seen again underlying the limestone in Lamb Lane.

From Lamb Lane northward to Sandbeck there are no very good exposures of these beds, but they are now and then seen in the ditches or ploughed up in the fields. The moist ground helps to mark out their line of direction. The upper boundary is generally well marked by the springs thrown out at the base of the Upper Limestone, but the lower is often very uncertain, and this is generally caused by the marls being washed down over the junction, as is the case between Letwell and Sandbeck. On the east side of Sandbeck Park there is a pit of soft red sand, and in a deep ditch just outside the park may be seen both marls and sandstones. On the east side of the turnpike road at Malpas Hill, in the sand pit, marked on the map, a semi-consolidated sand may be seen, rather coarse, with concretions of red marl and a few small scattered pebbles. The colour of the sand varies, being brown, yellow, red, and of all intermediate shades. A little farther to the east of this pit, below a limestone quarry, these beds may be seen again, only more consolidated and with more pebbles. Here they appear to be faulted against the Upper Limestone; but the junction is not very clear.

These sandstones with pebbles were, at this spot, taken at first to belong to the Pebble beds of the Bunter series, thrown down by a fault, but they slightly differ from the nearest known beds of that formation; and they are not different from the other beds underlying the Upper Limestone.

I do not know of any other good exposure of these marls and sandstones either in Sandbeck Park or north of it up to the borders of the district. The upper boundary, as before stated, is well marked and the lower obscure. The marls in some places contain beds of Gypsum, which farther to the north was formerly extensively worked; but the pits (still known as the "Plaster Pits") are now all abandoned. There is only one spot in this district, that I have ever heard of, where Gypsum has been obtained; namely, that mentioned by PROFESSOR SEDGWICK as occurring on the road that leads from Oldcoates to Firbeck; but no traces of these workings now remain.

THE UPPER MAGNESIAN LIMESTONE.

The Upper Limestone beds differ considerably in general appearance from those of the Lower Limestone, being thinner bedded, of a much finer grain, and their fracture, instead of being bright and crystalline, is dull and earthy. I also believe that the percentage of carbonate of magnesia in these strata is very small. The colours of the stone are grey, yellow, and light-brown, often spotted with small dark markings. PROFESSOR SEDGWICK, in

describing the limestone, says:—"The thin-bedded structure is "universal, not unusually passing into a structure which is slaty "and sometimes foliated. Between these beds, and even between "the foliations, there is generally interposed a very thin plate of "bluish-grey or greenish-grey marl; and when these marls "become so thick as to assume the character of beds (which is, "however, rarely the case), they have then generally a tinge of "red or purple. When seen in a quarry or natural section, the "thinner beds have an irregular shattered appearance; and when "one of them is struck with a hammer, it generally falls into "pieces at a number of natural joints, which are coated over with "beautiful, black, dendritic or stellated impressions."*

The Upper Limestone may be said to have its beginning as a continuous formation in this district, for although it does occur farther south, it is there only in the form of two small outliers.† The most southern point where the limestone has been observed here is at a small quarry on the top of a tump, between Gateford and Ramoth Gilead. The stone is fine-grained and earthy, and contains a few fossils. I did not here see the bottom of this formation, but I have no doubt but that it is exceedingly thin, for it was passed through in sinking a well about 10 chains to the north-east of Ramoth Gilead, and it was there only a few feet thick, with sandstone both above and below. The limestone was formerly quarried and burnt for lime in a field a quarter of a mile to the north of Ramoth Gilead; but for some distance north of that spot it is not traceable.

There are two small outliers on Gateford Hill. The one north of the house has been opened at the north-east corner of Ashwood, but its extent and outline is very uncertain, the ground being much covered by drift-gravel and sand. The smaller outlier is only known by fragments of limestone grubbed up by the plough.

The limestone is next seen in a quarry south of Carlton, where a few fossils were observed. There are also many quarries north of Carlton, and in the neighbourhood of Oldcoates the limestone abounds with fossils, chiefly of one species, *Myalina Hausmanni*. The following were collected here.

Myalina (*Mytilus*) *Hausmanni*, Goldf.
Schizodus (*Axinus*) *truncatus*, King.
S. Schlotheimii, Geinitz.

In the neighbourhood of Tickhill there are many extensive quarries, forming the best display of this Upper Limestone in this district. Its lower beds form a well-marked ridge, capping the Permian Marls.

Upper Marls.

These beds only make their appearance between the Upper Magnesian Limestone and New Red Sandstone in two places in

* Rev. A. Sedgwick, *Trans. Geol. Soc.* ser. 2, vol. iii., p. 103.
† See Geological Map, 82 S.E.

this district, one on Whin Common, north-east of Oldcoates, and the other near Carlton.

The only good section of these beds to be seen now is in the brickyard on Whin Common. They there consist of red and variegated marls, interstratified with thin shaly beds; but there are no sandstone beds like those that occur in the Middle Marls and Sandstones. There are traces of old clay pits near Hodsock Woodhouse in this formation. In digging the holes for the telegraph posts north of Carlton, red marls were dug up, evidently lying on the Upper Limestone. These are the only spots where I have observed these beds, and I was unable to trace them for any distance, as they (The Upper Red Marls) appear to be rapidly over-lapped by the New Red Sandstone.

NEW RED SANDSTONE.

In other parts of England hitherto mapped, the New Red Sandstone, when most complete, consists of the following formations:—

KEUPER STRATA	Red Marls and hard thin beds of Sandstone. Porous Sandstones and Marls (Waterstones). Fine and coarse Sandstones and Breccia (absent in this district).
BUNTER „	Upper Red and Mottled Sandstone (absent in this district). Conglomerate or Pebble Beds. Lower Soft Red and Mottled Sandstone.

Bunter Sandstone.

The Lower Soft Red and Mottled Sandstone of this district is a semi-consolidated fine sand, chiefly of a red colour, but sometimes mottled. The sand is often so fine and free from impurities as to be very valuable as a moulding-sand, some of which occurs near the Castle Farm in Worksop Manor Park. Sections of the Lower Soft Red Sandstone occur in many sand-pits and road-cuttings. On Sparking Hill, south of Worksop, the upper beds of this formation may be seen, and some of the lowest of them on Castle Hill at Worksop. In a sand-pit near the Worksop Railway-station there is brownish-red sand, and in the cutting west of the Station the lowest beds are exposed; and also in the sand-pits by the side of the road leading from Worksop to Shireoaks. In these places the sand is only partially consolidated. Between Gateford and Gateford Villa some of the beds are rather more consolidated. There are sections on the road leading from Worksop to Carlton, and in some of the lanes leading from that road up to the Forest Lands. There are not many places in the northern half of the county where these beds are well exposed. They may be seen in a pit south of Hodsock Woodhouse, in a deep ditch on the east side of Whitewater Common; and the upper beds may be seen in the cutting at the bottom of Spittle Hill, on the road from Tickhill to Bawtry.

This formation gets very thin towards the north, in which direction also its lower boundary becomes very obscure, the country being covered either with peat or a drift of sand and gravel. From the same cause the extent of the outlier at Tickhill is doubtful, sections of the sand being only seen at Tickhill Castle and in the sandpit in Sutherland Street; but it is found in the wells, and was also turned up in digging the holes for the telegraph-posts.

The Pebble Beds and Conglomerates of the Bunter Sandstone consist of coarse sand with pebbles, consolidated, unconsolidated, and in all intermediate stages. The colours of this formation vary between yellow and red; but its peculiar character consists in its pebbles, which occur either loosely scattered amongst unconsolidated sand, or forming a consolidated, hard and compact conglomerate. The pebbles are for the most part quartz, small, well-rounded and of various colours, white and red predominating; but besides the quartz there are pebbles and fragments of other rocks. There is a perfect conformity between the Lower Soft Red Sandstone and the Pebble Beds, and so gradually does the one pass into the other that it is often difficult to determine where to take the line of separation. A section showing the junction-beds may be seen on Sparkin Hill, and a good exposure of the Pebble Beds occurs in a deep cutting on the Worksop and Retford Road, where it is crossed by the Manchester, Sheffield, and Lincoln Railway. Cuttings on the line of railway between Worksop and Retford also show excellent sections of these formations.

In Long Acres Lane, east of Carlton, the junction of the Lower Soft Red Sandstone and Pebble Beds may be seen. The lower part of the section is a soft and thin-bedded sandstone with a little marl; and as we rise the sand gets coarser and then a few pebbles make their appearance. In the road north of Long Acres Lane there is a good section of the Pebble Beds, consisting of red and brownish-red compressed sand, containing pebbles of quartz and marl concretions. Both north and south of Blyth these beds are well exposed in the road-cuttings. One of the best sections, showing the gradual passage of the Lower Soft Red Sandstone into the Pebble Beds is on the rise of Spittle Hill, east of Tickhill, where a thickness of about 30 feet of sandstone is laid bare. At the lowest part of the section there is a soft red. sandstone without any pebbles; but higher up these begin to appear, at first few and gradually getting more numerous till the top beds become coarse sandstones with numerous pebbles. There are not many sections of the Pebble Beds over the central and eastern parts of its range; but there are a few exposures on and round Barrow Hill, between Bawtry and Everton, and on Blaco Hill and at Sound. It is not the nature of this formation to afford many natural sections, therefore the chief exposures of it are in road-cuttings and in gravel or sand-pits; but wherever seen has always the same character, only varying in amount of consolidation and in number of pebbles. The soil over this formation is light and poor, being chiefly sand or gravel. The part of the

country over which it spreads is well known as the "Forest Lands," being a portion of the Forest of Sherwood.

KEUPER.

Waterstones.

This formation occupies but a very small area in this district. It lies immediately above the Pebble Beds on the eastern side but there is no passage from the one into the other. There are many sections of the Waterstone series, for the marls and sandstones composing it are much used for brick and tile making. One of these brick-yards is on the west side of Garnston Covert, and here the bottom beds of the Waterstones are exposed, consisting of stiff blue clays with beds of light-coloured sandstone. Close by on the west side of this clay-pit is another pit in the Pebble Beds; the lowest bed seen is a coarse yellow sand with a few pebbles, and over this is 5 or 6 feet of red sand without pebbles. The beds dip E. 20° N. 8°.

At Garnston there are some sections of higher and more characteristic Waterstones, consisting of soft porous sandstones, varying in colour from whitish-brown to reddish-brown.

A very good section showing the junction between the Pebble Beds and the Waterstones is exposed in a cutting on the Manchester, Sheffield, and Lincoln Railway at Retford, on the east side of the bridge under the Great North Road. There, at the base of the section, may be seen thick beds of coarse yellow sandstone with oblique lines through the bedding. The upper surface of this conglomerate is quite smooth, and on it lies about 2 feet of thin beds of sandstone and red shale, and over this white shales and sandstones making a white clay, which in other places is light blue. There is a slight dip to the east of one or two degrees. There is a another junction to be seen in a brick-yard near the gasworks. Here, the Pebble Beds are red in colour, with a few scattered pebbles, and the clay for brick-making is prepared from light-blue shaly marl and light-brown soft sandstones with a few red blotches. Another excellent junction may be seen by a roadside leading from Retford to Bottom Mill. In all these sections the contrast between the two sets of beds is very marked.

About a couple of miles north of Retford the boundary between the Pebble Beds and the Waterstones bends to the east, carrying the latter formation outside the eastern border of the district; but about 3 miles further north a fault throws it back again, and with it a small patch of the Upper Keuper Marls. This fault, which has an east and west strike, crosses the Chesterfield Canal at the north end of the Drakehole Tunnel; and here the Upper Keuper red marls and white sandstones are brought down against the Pebble Beds, the downthrow of the fault being towards the north.

In the brick-yards east of Everton the clay is chiefly white or

blue, being the bottom beds of the Waterstones, and there does not appear to be in this part of the country those beds of brown and soft porous sandstone that characterise the same formation near Nottingham. A small section of white clays and red marls is exposed in the dyke alongside the Blackbank Road.

The boundary between the Pebble Beds and the Waterstones is not clearly shown north of Everton. White clay may be seen at the bottom of some of the drains, and at other places the ground is sandy; and these form the only guides in tracing the boundary-line.

DRIFT.*

A drift of sand or gravel is to be found everywhere spread over this district, sometimes so thickly as entirely to obscure the rocks beneath. But it is in the eastern part where the drift is in greatest force, being chiefly derived from the breaking up of the Pebble Beds of the New Red Sandstone, that formation often being completely buried in its own débris. Barrow Hill, east of Bawtry, is covered with sand and gravel, derived chiefly from the Pebble Beds. The sand, I believe, is entirely derived from them: but, while the Pebble Beds are chiefly made up of quartz and hard sandstone pebbles, the gravel (besides these) contains fragments of Magnesian Limestone, Coal-Measures, and other rocks, very little rounded. In the gravel-pits on Barrow Hill the Pebble Beds themselves may be seen below the gravel. These pits show a very good example of the drift-gravels over this district; and I need not allude further to others, many of which are marked on the map. Over the western half of the district, though the drift is there not so thick as in the east, I often found it very troublesome to trace the boundary-lines of the various stratified rocks. It is very seldom that the ground is entirely clear of it, for in going over any part of the country where the rocks are well exposed and apparently uncovered by drift, a few pebbles are sure to be seen scattered over the ploughed fields mixed with fragments of the rock beneath. Besides the drift of gravel and sand, there is another superficial deposit of clay. To all appearance

* Though the word "drift" is here used, it is not intended to refer any of the superficial deposits of this district to any glacial drifts (the "Upper" or "Lower Boulder Clay" or "Middle Sands and Gravels"). I believe they are of later date and chiefly derived from local sources, the sands and gravels being mainly derived from the denudation of the Bunter sandstones. What few foreign pebbles there are may have been derived from the breaking up of some old glacial deposit, of which no trace is left.

The brown clay in the brick-yard east of Harworth was evidently tranquilly deposited either at the bottom of a lake or an estuary of the sea. I have stated that I believe that it is of the same age as the clays near Doncaster, which are the old warp clays of the Humber.

It is true I have not examined these superficial deposits since I mapped the country more than twenty years ago, when little was known or written on the theory of the glacial origin of the drift. It is possible, if the district is ever resurveyed for the purpose of publishing a map of the superficial deposits, some new light may be thrown on the origin of these sands and gravels. May, 1879.

this clay is older than the gravels. It only occupies a limited area in this district, and there is only one good section of it, which I will describe.

In a brick-yard (marked on the map) east of Harworth, a village to the south-east of Tickhill, there is exposed 15 feet of yellow sand and pebbles and lines of carbonaceous matter, roughly stratified, and there is no doubt of its being drifted. Below the sand and gravel there has been cut open a face of between 15 and 20 feet of brown clay, the bottom of which has not been reached. The clay is nearly homogeneous and of the same colour throughout, being brown with a tint of purple. Some parts of the clay may be of stiffer quality than others. As far as I could see, the clay was entirely free from pebbles or fragments of rock of any kind, but I obtained from a workman two small lumps, one resembling chalk and the other of coal, which he informed me he had found in the deepest part of the pit. There is a strong line between the clay and overlying gravel. The clay is extensively worked here for brick-making, having something of the consistency of the London Clay, which it resembles also in colour. Although this is the only place in this district where it is worked and also seen, it is extensively developed in the Doncaster district, where there are many brick-yards on it, and when the memoir of that district is written its position among the superficial deposits will be more fully entered into than it can be here. I believe this clay may be found below the peaty ground through which the river Thorn flows east of Tickhill, because this is the sort of ground that often covers this same clay in the Doncaster district. It also, I believe, occurs in the low ground near Bawtry and Scrooby, and in the districts further north, where it conceals the underlying rocks.

ALLUVIUM.

The Alluvium shown on this map is the mud supposed to have been deposited by the river Idle over the flat land through which it flows. The depth of this deposit and its precise limits are very uncertain.

PHYSICAL GEOLOGY.

Unconformities.

One of the peculiar features in the geology of this district is the unconformity between the various formations even when they are otherwise closely connected. The red sandstones of Harthill, &c., are to all appearances quite unconformable to the Lower Coal-Measures below them, and yet the same fossils are found in both, and they are surmounted by other coal-bearing strata. The break between the Carboniferous and the Permian is one of importance and great magnitude, the Permian rocks

lying indifferently on any part of the Carboniferous series.* The unconformity between these formations is so great that rocks of Permian age may be often seen resting nearly horizontally on the upturned edges of Carboniferous strata, showing that the latter was upheaved and denuded before the deposition of the former. In the Permian series itself there is a good deal of unconformity, for there is a break between the Lower Limestone and the Middle Marls and Sandstones, the latter overlapping the beds of the former. One instance of this occurs in the valley west of Shireoaks, where the marls extending up that valley rest at their western extremity on very low beds, close to the bottom of the Lower Limestone, and in such a manner as to show that the limestone beds must have been upheaved and denuded before the Middle Marls and Sandstones were deposited. Between the Middle Marls and Sandstones and the Upper Limestone there is some amount of conformity if they do not actually pass into each other; but even here I think there must be occasional overlaps, to judge by the varying breadth of the lower beds. I cannot form an opinion as to how the Upper Marls behave, as they are but little exposed. Notwithstanding the break there must be between the Upper and Lower Limestone and their differences in mineral character and structure the same fossils occur in both, though in different proportions. This is not very evident from the scanty lists given in this explanation, but collections from neighbouring localities show that there are no species in the upper beds which are not also present in the lower.

The break between the Permian strata and the New Red Sandstone is well shown in this district by the lower beds of the Bunter Sandstone overlapping the upper Permian Marls throughout most part of it, and all the Upper Limestone south of Gateford. There is no break in the Bunter series between the "Lower Soft Red Sandstone" and the Pebble Beds, which pass gradually into each other, but between the Bunter and the the Keuper strata there is quite a marked discordance, as may be seen in sections showing the junctions and already described in this memoir.

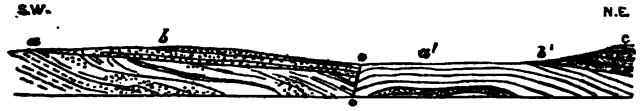
Faults.

The next feature in the geology of this district that I shall notice are the faults or dislocations in the strata. These are not many in number, but there are a few large enough to throw the rocks much out of their regular courses.

At South Anston the red sandstones strike away from the lime-

* The line of division between the Carboniferous and the Permian forms the true division between the Primary and Secondary formations, though hitherto that line of division has been taken at the top of the Permian; but this arose chiefly in consequence of the Harthill Red Sandstones and certain red-stained Carboniferous rocks of all ages lying below the Magnesian Limestone having been included with the Permian under the name of Roth-liegende (Murchison) or Lower Red Sandstone (Sedgwick). Also the Upper Coal-Measures of Staffordshire and Warwickshire, with their Carboniferous flora, being of a red colour were formerly considered Permian. May 1879.

stone in a north-westerly direction, and the beds dip towards the north-east, as if going below the clay-lands on that side. I believe this is not really the case, and that both the strike and dip of these beds is caused by a fault along the north-east boundary, this fault being a downthrow to the south-west, the South Anston beds being those of North Anston, repeated to the south-west. The diagram below will explain this.



a Lower Coal-Measures. *b* Red Grits of upper Coal-Measures.
c Magnesian Limestone. *a'* Lower Coal-Measures N.E. of Fault.
b' Red Grits under the Limestone. * * Fault.

The proof of the above fault is as follows:—

If the beds marked *b* in the diagram were really lower than the Lower Coal-Measure strata marked *a'*, there is no reason why they should end so suddenly in their strike to the north-west, as they seem to do on the border of the adjoining district. The lower boundary, however, of these strata turns round and meets the north-east boundary line, just as it must do if the north-eastern boundary were a line of fault, which is further proved by the fact that the strata along the north-eastern line are probably about 100 feet above the basement beds, which at Hardwick curve round to meet the fault.

Another fault, nearly parallel to this, passes through Kiveton Park Station. This one is a downthrow to the north and appears to be of considerable magnitude, for the Magnesian Limestone is much higher on the south side of the fault than it is on the north. The beds on the north side of this fault dip abruptly northward at an angle of 30°, but they do not keep this dip long, for in the quarries to the north of the railway the beds dip south. This fault and dip of the beds will be better understood by the section below, taken across the line of disturbance.

a Coal-Measures. *b* Red Grits. *c* Clay.
d Magnesian Limestone. * Fault.

This same fault is supposed to have thrown down the Middle Marls and Sandstones of the valley west of Shireoaks. The direction it takes eastward of the valley is uncertain. It may form the boundary between the Middle Marls and the Lower Soft Red Sandstone at Clay Lands, or the fault may have taken place before the deposition of the New Red Sandstone.

There appear to be some small faults at Gateford, but they are rather uncertain, there being no very clear section there showing the junction of the limestone and sandstone; but the limestone on

the hill between Gateford and Ramoth-Gilead, as well as the two outliers of limestone on Gateford Hill, are on a much higher level than the New Red Sandstone on the south side of the hamlet, and no limestone has been found under the sandstone between these farms and Gateford Hall. This absence of the limestone may be explained by means of an overlap; but the occurrence of the sandstone at so low a level cannot be accounted for in the same way. Faults, as marked on the map, would explain the phenomena as being downthrows towards the south.

The fault near Everton has been before noticed in describing the formations it affects.

There is probably a fault crossing Maltby Common and throwing down the Middle Marls; for they occur at a much lower level than the limestone on the south side of the Common, which rises from it in a steep bank or cliff running north-west and south-east, the marls coming against its foot as if they were below instead of above the limestone. The only other way of accounting for the peculiar position of these beds is to suppose that the cliff was formed before the marls were deposited, which is very improbable.

Judging by the soil only (for the rocks themselves are not exposed) the limestone north of Fardell's House is brought rather suddenly against some red beds. This may or may not be caused by a small fault, with a downthrow towards the south.

Dip of Strata.

The dip of the Magnesian Limestone series as well as of the New Red Sandstone is, on the whole, towards the east at an inclination very seldom exceeding 5°, but generally of a less amount, especially in the higher formations. The result of this small dip is the prolongation down the valleys when they slope to the east of a small tongue of the underlying rock, while the upper rock forms the sides of the valley for a considerable distance. The dip of the beds in these cases is the same, or not much greater, than the angle at which the surface of the ground of the valley falls. Examples of this are found in the valleys from Maltby and Brookhouse to Roche Abbey, the Stones Dyke Valley, and also in the valley from Bondhay to Shireoaks, where the same beds of limestone can be traced, forming the bank or cliff, for a considerable distance.

Soils.

The Lower Coal-Measures generally have a wet and cold stiff clay soil except when the yellow sandstone forms the surface, then the soil is sandy. The red sandstone of the Upper Coal-Measures furnishes a red sandy soil.

The Lower Magnesian Limestone forms generally high and dry ground with a light arable soil. It rises from the Coal-measure

country with a steep escarpment, and then slopes down gradually to the ground occupied by the Middle Sandstones and Marls, which form a wet and heavy soil, when not too thickly covered by drift. The Upper Magnesian Limestone ground rises, like that of the Lower with a steep escarpment to the west, and also forms good arable soil, having its more gentle slope to the east. The Pebble Beds form another steep ridge with a westerly face, and this ground with many undulations slopes towards the valley of the Idle. All the tract occupied by the Bunter Beds has a light sandy or gravelly soil, and that of the Keuper strata, when not covered by drift, is a stiff red clay.

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108. St. Helen's, Burton Wood.
109. Winwick, &c. 6s.
111. Cheedale, part of Stockport, &c.
112. Stockport, &c. 4s.
113. Part of Liverpool, &c. 4s.

Durham.

Scale, six inches to a mile.

Sheet.
1. Ryton. 4s.
2. Gateshead. 4s.
3. Jarrow. 4s.
4. S. Shields. 4s.
5. Greenside. 4s.
6. Winlaton.
7. Washington.
8. Sunderland.
9. ——— 4s.
10. Edmond Byers. 4s.
11. Ebchester.
12. Lantoydy.
13. Chester-le-Street. 6s.
14. Chester-le-Street.

Durham—cont.

Sheet.
16. Hunstanworth.
17. Waskerley.
18. Muggleswick.
19. Lanchester. 6s. Vertical Section, 39.
20. Hetton-le-Hole.
24. Stanhope.
25. Wolsingham.
26. Brancepeth.
32. White Kirkley.
33. Hamsterley.
34. Whitworth.
41. Cockfield.
42. Bishop Auckland.

Northumberland.

Scale, six inches to a mile.

47. Coquet Island. 4s.
56. Druridge Bay, &c.
63. Netherwitton.
65. Newbiggin. 4s.
68. Belingham.
69. Redesdale.
72. Bedlington.
73. Blyth. 4s.
77. Swinburn.
78. Ingoe. 6s.
80. Cramlington.
81. Earsdon.
84. Newborough.
85. Chollerton.
86. Matfen.
87. Heddon-on-the-Wall.
88. Long Benton.
89. Tynemouth.
92. Haltwhistle.
95. Corbridge.
96. Horsley. 4s.
97. Newcastle-on-Tyne. 4s.
98. Walker. 4s.
101. ———
102. Allendale Town.
105. Newlands.
107. Allendale.
108. Blanchland.
109. Shotleyfield.
110. Wellhope.
111. Allenheads.

Yorkshire.

100. Limley.
184. Kelbrook.
201. Bingley.
204. Aberford.
216. Bradford.
217. Calverley.
218. Leeds.
219. Kippax.
231. Halifax.
232. Birstal.
233. East Ardsley.
234. Castleford.
246. Huddersfield.
260. Honley.
272. Holmfirth.
273. Penistone.
274. Barnsley.
275. Darfield.
276. Brodsworth.
281. Langsell.
282. Wortley.
283. Wath upon Dearne.
284. Conisborough.
287. Low Bradford.
288. Ecclesfield.
289. Rotherham.
290. Braithwell.
293. Hallam Moors. 4s.
295. Handsworth.
296. Laughton-en-le-Morthen
299. ———.
300. Harthill.

SCOTLAND.

Scale, six inches to a mile.

Edinburghshire.

2. Edinburgh, &c.
3. Portobello, Musselburgh, &c.
6. Gilmerton, Burdie House, &c.
7. Dalkeith, &c.
8. Preston Hall. 4s.
12. Penicuick, Coalfields of Lasswade, &c.
13. Temple, &c.
14. Pathead. 4s.
17. Brunston Colliery, &c.
18. Howgate.

Haddingtonshire.

Six inches to a mile.

8. Prestonpans, &c. Price 4s.
9. Trenent, Gladsmuir, &c. Price 6s.
13. Elphinstone, &c. Price 4s.
14. Ormiston, East Salton, &c.

Fifeshire.

Six inches to a mile.

24. Markinch, &c.
25. Scoonie, &c.
30. Beath, &c.
31. Auchterderran. 4s.
32. Dysart, &c.
33. Buckhaven.
35. Dunfermline.
36. Kinghorn.
37. Kinghorn. 4s.

Ayrshire.

Six inches to one mile.

19. Newmilns.
26. Glenbuck. 4s.
27. Monkton, &c.
28. Tarbolton, &c.
30. Aird's Moss.
31. Muirkirk. 4s.
33. Ayr, &c.
34. Coylton.
36. Grieve Hill.
40. Chiltree.
41. Dalleagler.
42. New Cumnock.
46. Dalmellington.
47. Benbeock.
50. Daily.
52. Glenmoat.

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